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# Distributed Service Level Management For Network Traffic

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# Distributed Service Level Management For Network Traffic

## BACKGROUND OF THE INVENTION

### 1. Field of the Invention

The present invention relates to the field of networking. More specifically, the present invention addresses the issue of managing service level goals or commitments for a group of network traffic serviced by a networking device (such as a "router").

### 2. Background Information

With advances in integrated circuit, microprocessor, networking and communication technologies, increasing number of devices, in particular, digital computing devices, are being networked together. Devices are often first coupled to a local area network, such as an Ethernet based office/home network. In turn the local area networks are interconnected together through wide area networks, such as ATM networks, Frame Relays, and the like. Of particular notoriety is the TCP/IP based global inter-networks, Internet.

As a result of this trend of increased connectivity, increasing number of applications that are network dependent are being deployed. Examples of these network dependent applications include but are not limited to, email, net based telephony, world wide web and various types of e-commerce. For these applications, success inherently means high volume of network traffic for their implementing servers. To ensure continuing success, quality of service through orderly and efficient handling of the large volume of network traffic has become of

paramount importance. Various subject matters, such as scalability, distributive deployment and caching of contents, as well as achieving and maintaining service level goals or commitments by networking devices have become of great interest.

The capabilities and capacity of a networking device are probably the primary factors in determining the networking device's ability in meeting its service level goals/commitments, whether the goals/commitments are reliability or performance oriented. However, in a shared networked world, having plenty of capabilities and capacity in and of themselves does not automatically guarantee that the networking device will be able to meet its service level goals/commitments. Unexpected or unplanned surges/increases in "non-essential" or "superfluous" network traffic potentially could cause congestion, and adversely impacts the networking device's ability to service the "essential" network traffic.

Various bandwidth reservations or priorities based schemes (attributed to individual packets or packet types and self-administered by the networking devices having the service level goal/commitments) are employed in the art to ensure that the appropriate service levels are provided. However, these schemes impose the burden on the networking device "struggling" to meet the service level goals/commitments, further compounding the problem. Moreover, the various schemes are tend to be complex and difficult to implement. Thus, alternate approaches to enhancing the likelihood of a networking device's ability to meet its service level goals/commitments are desired.

## SUMMARY OF THE INVENTION

One or more networking apparatuses are employed to practice a networking method that improves a networking device's likelihood in meeting its service level goals/commitments for a first group of network traffic serviced by the first networking device. Determination is made, away from the networking device, on whether the network device is meeting the service level goals/commitments for the first group of network traffic. Determination may include monitoring the first group of network traffic at or away from the networking device. If the service level goals/commitments are not being met, at least a second group of network traffic (also serviced by the first networking device) is selected for regulation. Regulation may be made at the networking device or away from the network device, at other nodes of the network.

Additionally, if the condition for regulation no longer presents, regulation may be moderated or removed. Further, the service level goals/commitments may include reliability and/or performance goals/commitments.

## BRIEF DESCRIPTION OF DRAWINGS

The present invention will be described by way of exemplary embodiments, but not limitations, illustrated in the accompanying drawings in which like references denote similar elements, and in which:

**Figure 1** illustrates a network view of the present invention, including a sensor function and a director function, in accordance with one embodiment;

**Figure 2** illustrates a method view of the same invention, in accordance with one embodiment;

**Figure 3** illustrates a component view of the sensor function, in accordance with one embodiment;

**Figures 4-6** illustrate the operational flow of the relevant aspects of the requestor, reporter and command application functions of **Fig. 3**, in accordance with one embodiment each;

**Figure 7** illustrates an architectural view of a sensor, in accordance with one embodiment;

**Figure 8** illustrates a component view of a director function, in accordance with one embodiment;

**Figures 9-11** illustrate the operational flow of the relevant aspects of the send/receive, analyzer and regulator functions of **Fig. 8**, in accordance with one embodiment each; and

**Figure 12** illustrates an example computer system suitable for use to host a software implementation of the sensor or the director function, in accordance with one embodiment.

## DETAILED DESCRIPTION OF THE INVENTION

The present invention provides a novel approach to distributively manage service level goals/commitments for a group of network traffic serviced by a networking device (such as a "router"). In the description to follow, various aspects of the present invention will be described. However, the present invention may be practiced with only some of the aspects described. For purposes of explanation, specific numbers, materials and configurations are set forth in order to provide a thorough understanding of the present invention. However, the present invention may be practiced without some of the specific details described. In other instances, well known features are omitted or simplified in order not to obscure the present invention.

Parts of the description will be presented in terms of operations performed by a processor based device, using terms such as requesting, reporting, determining, data, and the like, consistent with the manner commonly employed by those skilled in the art to convey the substance of their work to others skilled in the art. The "quantities" or the "objects" of the various operations take the form of electrical, magnetic, or optical signals capable of being stored, transferred, combined, and otherwise manipulated through mechanical and electrical components of the processor based device. The term processor includes microprocessors, micro-controllers, digital signal processors, and the like, that are standalone, adjunct or embedded.

Various operations will be described as multiple discrete steps in turn, in a manner that is most helpful in understanding the present invention, however, the order of description should not be construed as to imply that these operations are

necessarily order dependent. In particular, these operations need not be performed in the order of presentation.

The terms "router" and "route" are used throughout this application, in the claims as well as in the specification. The terms as used herein are intended to have a broader meaning than its normal plain meaning as understood by those ordinarily skilled in the networking art. They are intended to be genus terms that include the conventional routers and conventional routing, as well as all other variations of network trafficking, such as, switches or switching, gateways, hubs and the like. Thus, unless particularized, the terms are to be given this broader meaning.

Further, the description repeatedly uses the phrase "in one embodiment", which ordinarily does not refer to the same embodiment, although it may.

## Overview

Referring now first to **Figure 1**, wherein a block diagram illustrating a network view of the present invention, in accordance with one embodiment, are shown. As illustrated, in accordance with the present invention, network traffic is distributively managed for a networking device, such as routing device **106**, to enable the networking device to meet the service level goal(s) or commitment(s) for a group of network traffic, such as network traffic **107a**, serviced by the networking device. For the illustrated embodiment, network traffic is distributively managed employing director function **102**, augmented with sensor function **104**. More specifically, director function **102**, assisted by sensor function **104**, is employed to reduce the negative impact of other network traffics, such as network traffic **107b**, on the ability of routing device **106** to meet its service level goals or commitments for network traffic **107a**. Typically, although not necessarily, the other network traffics to be

regulated are other network traffics also serviced by the networking device of interest.

The present invention contemplates that the service level goals/commitments may be one of a variety of reliability, performance as well as other service level goals/commitments of like kinds. The term "service level goals" as used herein generally refers to "self-imposed" desired service levels, whereas the term "service level commitments" generally refers to desired service level commitments made to "clients" of the networking devices of interest. For the purpose of practicing the present invention, the two terms are synonymous. In other words, as far as practicing the present invention, there are no substantive differences between distributively managing for service level goals versus managing for service level commitments. Accordingly, hereinafter, the two terms may be used interchangeably.

For the illustrated embodiment, network traffics **107a** and **107b** are destined for or sourced from destination/source **108a** and **108b** respectively. As illustrated, destination/source **108a** and **108b** may be a server, a routing device or a network of servers/networking devices. Moreover, for alternate embodiments, destination/source **108a** and **108b** may be the same destination/source. That is, network traffics **107a** and **107b** may be network traffics destined for the same destination node/network, but sourced from different clients of the destination node/network. In other words, network traffics may be managed for a beneficiary server, favoring one of its clients over other clients.

Briefly, director function **102** (assisted by sensor **104**, for the illustrated embodiment) distributively determines, away from routing device **106**, whether routing device **106** is meeting its service level goals/commitments for network traffic **107a**. If not, other network traffics, such as network traffic **107b**, are distributively

identified (away from routing device **106**) and regulated to assist routing device **106** in meeting its service level goals/commitments for network traffic **107a**. Regulation of network traffics **107b** may be applied at routing device **106** or other locations, i.e. networks nodes (not shown) of network **100**.

In due course, director function **102** (assisted by sensor **104**, for the illustrated embodiment) also distributively determines, away from routing device **106**, whether the condition or conditions that cause the inability of routing device **106** to meet its service level goals/commitments for network traffics **107a** still present. If the condition or conditions no longer present, director function **102** distributively determines, away from routing device **106**, where in network **100** and by how much regulation should be moderated (i.e. de-regulating previously imposed regulations).

Network **100** is intended to represent a broad range of private as well as public networks or interconnected networks, such as the enterprise network of a multi-national corporation, or the Internet. Except for the manner network traffics are distributively managed, networking nodes, such as, routing device **106**, or **108a** and **108b**, or servers **108a-108b** or "sub"-networks **108a-108b**, are all intended to represent a broad range of network trafficking equipment/entities. In the case of routing devices **106** or **108a/108b**, they may include but are not limited to conventional routers, switches, gateways, hubs and the like.

In one embodiment, director function **102** and sensor function **104** are implemented on one or more network management devices separate and distinct from routing device **106**, as illustrated in **Fig. 1**. In alternate embodiments, director function **102** and sensor function **104** may be implemented on the same network management device, and the "network management" device may be routing device **106** itself (self-manage).

The coupling between the implementing device or devices of director and sensor functions **102** and **104** may be made using any one of a number of communication links known in the art, such as modem links over conventional phone lines, Digital Subscriber Lines (DSL), Integrated Service Digital Network (ISDN) connections, Asynchronous Transfer Mode (ASM) links, Frame Relay connections, and the like.

While for ease of understanding, only one director function **102**, one sensor function **104**, a router **106**, and a handful each of network "nodes" **108a-108b** are included in the illustration, from the description to follow, it will be readily apparent that the present invention may be practiced with more than one director function **102** as well as more or less network "nodes" **108a-108b**, routing devices **106** and sensor functions **104**. If more than one director function **102** is employed, typically when a larger number of sensor functions **104** are employed, each director function **102** may be assigned responsibility for a subset of the sensor functions employed. The director functions may relate to each other in a master/slave relationship, with one of the director functions serving as the "master" (and the others as "slaves"), or as peers to one another or organized into a hierarchy. Further, a sensor function may monitor multiple routing devices.

Having now provided an overview of the present invention, we further refer to **Figure 2**, wherein a method view of the present invention, in accordance with one embodiment, is shown. As illustrated and alluded to earlier, the method starts with director function **102** determining (away from routing device **106**) whether routing device **106** is meeting its service level goals/commitments for network traffic **107a** (block **204**). Upon determining the routing device **106** is not meeting its service level goals/commitments for network traffic **107a**, director function **102** identifies (away

from routing device **106**) a group of other network traffic that substantially contributes to the inability of routing device **106** in meeting its service level goals/commitments (block **206**). Upon identifying a group of other network traffic as a substantial contributor to the inability of routing device **106** in meeting its service level goals/commitments, director function **102** causes the identified other network traffic to be regulated accordingly (block **208**). As described earlier, the regulations may be applied at routing device **106** or at other locations of network **100**.

Back at block **204**, if it is determined that routing device **106** is meeting its service level goals/commitments, director function **102** determines (away from routing device **106**) whether at least one other group of network traffics is being regulated to assist routing device **106** in meeting its service level goals/commitments, and whether regulation may be moderated (block **210**). Upon determining that regulation may be moderated, director function **102** determines the locations and amounts of de-regulations, and causes the de-regulation to be applied accordingly (block **212**). As alluded to earlier, the de-regulations may be applied at routing device **106** or at other regulated locations of network **100**.

Having now also described the method of the present invention at a high level, we now describe a number of the aforementioned aspects in further details. Still referring to **Figs. 1-2**, as alluded to earlier and illustrated, sensor function **104** is employed to assist director function **102** in distributively managing network traffic for the benefit of routing device **106**. More specifically, sensor function **104** is employed to monitor network traffic **107b** as well as network **107a**. That is, sensor function **104** is employed to monitor the network traffics that substantially contribute to the inability of routing device **106** in meeting its service level goals/commitments (network traffic **107b**), as well the network traffic associated with the service level

goals/commitments of interest (network traffic **107a**). Of course, in alternate embodiments, network traffic may be monitored and reported by networking device **106** itself or with different sensors being employed.

For the illustrated embodiment, monitoring of network traffic **107a** and **107b** involves monitoring of various network traffic metrics for network traffic **107a** and **107b**. Typically, these network traffic metrics are at least partially indicative of whether routing device **106** is meeting its service level goals/commitments. For reliability goals/commitments, these network traffic metrics may include for example, packet drop rate. Similarly, for performance goals/commitments, these data may include for example, the volume of data being sent or transmitted, or the average turnaround time of the packets of network traffic **107a-107b**.

Further, for the illustrated embodiment, monitoring of network traffic **107a** and **107b** are performed at routing device **106**. However, in alternate embodiments, monitoring of network traffic **107a** and **107b** may be performed at other parts of network **100**. For example, upon determining the "typical" sources and destinations of network traffic **107a-107b**, sensor function **104** may perform the monitoring at the determined source and destination locations of the network **100** or routing devices near the determined source and destination locations (beside routing device **106**, the intended beneficiary).

For the illustrated embodiment, the monitor data are provided periodically (e.g. on request) to director **102**, which in turn performs its determination responsibilities based on the provided monitor data. However, in alternate embodiment, the monitor data may be provided continuously to director **102** instead.

Thus, for this embodiment, at block **204**, director **102**, in response to the receipt of the reported data, determines whether routing device **106** is meeting its service level goals/commitments for network traffic **107a**. The determination, may

be made, for example, by comparing the received metric data against a number of pre-provided corresponding thresholds for the data metrics. For the earlier mentioned example, data metrics such as packet drop rates, volume of data and average response time, the corresponding thresholds may be a maximum drop rate, a minimum amount of data, and a minimum average response time.

At block **206**, for the illustrated embodiment, director function **102** determines if another group of network traffic, such as network traffic **107b**, substantially contributes to the inability of routing device **106** in meeting its service level commitments, in accordance with configuration information pre-provided. In other words, director function **102** is pre-provided with the network traffic regulation candidates, and considers the candidates in order. In alternate embodiments, director function **102** may determine the candidates dynamically, e.g. by query routing device **106** for the "most active" network traffics.

Network traffics **107b** may be considered as being substantially contributing to the inability of routing device **106** in meeting its service level goals/commitments for a variety of reasons. For example, network traffics **107b** may be so considered because of the amount of bandwidth network traffics **107b** consume.

At blocks **208** and **212**, director function **102** causes regulations and de-regulations to be applied at networking device **106** or other selected locations of network **100**. For the purpose of this application, regulation in general means moderating the amount of the network traffic to be regulated, whereas, de-regulation generally means relaxing the amount of moderation being applied to a particular group of network traffic.

At its extreme, regulation could include completely blocking off network traffic of the particular kind. Examples of regulation actions include but are not limited to limiting the bandwidth available for, or lowering the priority of network traffic to be

regulated. Alternatively, a number of filters may also be applied to filter out the undesirable network traffic.

In its most fundamental form, de-regulation could simply involve resuming allowance of network traffic of the particular kind. Examples of moderation relaxation actions include but are not limited to the "inverses" of the regulation actions, i.e. expanding the bandwidth available for, or increasing the priority of the regulated network traffic. Examples of unblocking actions include but are not limited to cessation of filtering of the network traffic destined for or sourced out of the third party network node.

For the illustrated embodiment, at block **208**, director function **102** selects networking device **106** itself for regulation. In alternate embodiments, director function **102** selects routing device that are "closest" to networking device **106**, for regulation, and the regulation is iteratively and progressively extended outward, i.e. away from routing device **106**. For de-regulation, for the illustrated embodiment, director function **102** again selects networking device **106** itself. For the alternate "progressive" regulation embodiment, director function **102** may de-regulate in "reverse" order, starting the deregulation from the "outermost" regulated routing device (away from networking device **106**), and progressively retreat towards routing device **106**.

Regulations and de-regulations may be applied and relaxed on an iterative basis also. That is, regulation may be initiated at a relatively "low" predetermined level, and gradually increased over time. Alternatively, regulation may be initiated at a relatively "high" predetermined level, and gradually decreased over time. Similarly, any de-regulation may be started with a relatively "small" amount, and increased over time.

For block **210**, director function **102** may determine whether regulation may be relaxed by determining whether the conditions that caused network traffics **107b** to be regulated remain present. If the conditions no longer present, director function **102** determines where the regulation may be relaxed, e.g. at routing device **106**, or other regulated locations in network **100**, and additionally, the amount of deregulations at the selected de-regulation locations.

Note that under the present invention, regulation and de-regulation action such as bandwidth and priority regulations/de-regulations are dynamically determined and implemented, and no attribution of priority properties to the packets is necessary. In contrast, in the prior art, bandwidth reservations are pre-provisioned, and priorities are attributed to all packets. Further, priorities have be respected by all routers along the routing paths. Moreover, those skilled in the art will appreciate that the present invention is a superior approach, as the present invention is more flexible, works with a variety of routing capabilities, and generally, simpler to implement.

For the illustrated embodiment, director function **102** issues the regulation/de-regulation instructions to the applicable routing device **106** or others in network **100** via their corresponding sensor functions. That is, in the case of routing device **106**, the regulation/de-regulation instructions are provided to routing device **106** via sensor function **104**. Upon receipt of the instructions, applicable routing device **106** or others (or corresponding sensor function **104**) causes the desired regulation/de-regulation actions to be applied to effectuate the desired regulation/de-regulation on the targeted network traffic. In alternate embodiments, regulations and de-regulation instructions may be provided to the regulated/de-regulated devices directly.

## Sensors

**Figure 3** illustrates a component view of sensor function **104**, in accordance with one embodiment. The embodiment assumes that sensor function **104** is implemented on an externally disposed device, outside of its responsible routing device or devices (hereinafter, simply router or routers). Moreover, the regulation and de-regulation commands are issued to the routers through their responsible sensor functions **104**. As illustrated, sensor function **104** includes requestor function **302**, reporter function **304** and command application function **306** operatively coupled to each other as shown. Requestor function **302** is used to request a router or routers for data depicting network traffic routed through the router/routers. The request/requests may be made periodically or on demand. The request/requests may be made using any one of a number of communication protocols known in the art. As alluded to earlier, examples of such data are network traffic statistical data. Requestor **302** is also used to request a router or routers to alter its/their routing operations to effectuate a desired regulation/de-regulation on the router/routers, with respect to network traffic being serviced. The routing operation altering request commands are typically made as a result of regulation/de-regulation instructions provided by director function **102**. Similarly, the commands may be provided to the router/routers via any one of a number of communication protocols known in the art (e.g. defined by the router or other standard or proprietary protocol).

Reporter function **304** is used to report the gathered network traffic data. More specifically, reporter function **304** reports the gathered network traffic data to director function **102**. For the illustrated embodiment, the reporting are made periodically or on demand. The report may be made in any one of a number of formats, via any one of a number of communication protocols known in the art.

Command application function **306** applies the router specific commands responsive to the regulation/de-regulation instructions received from director function **102**. The specific commands are router vendor dependent.

**Figures 4-6** illustrate the operation flow of the relevant aspects of request function **302**, report function **304** and command generation function **306**, in accordance with one embodiment each. For request function **302**, as illustrated in **fig. 4**, upon start up, it awaits expiration of a timer, block **402**. The periodicity of expiration is application dependent. Upon expiration of the timer, at block **404**, request function **302** requests its responsible router/routers for network traffic data of the network traffics of interest. At blocks **406** and **408**, request function **302** accumulates and saves the network traffic data provided. Upon completion of the data transfer, requestor function **302** returns to block **402**. However, if timer has not expired, block **402**, request function **302** determines if any regulation/de-regulation commands are to be sent to its responsible router/routers, block **410**. If there are commands queued awaiting transmission to the router/routers, request function **302** dequeues and sends the commands to the router/routers accordingly, block **412**. Upon sending the commands, request function **302** returns again to block **402**.

For report function **304**, as illustrated in **fig. 5**, in like manner, upon start up, it awaits for the expiration of a timer, block **502**. Likewise, the periodicity of expiration is application dependent. Upon expiration, i.e. time for reporting, report function **304**, takes the most recently received and saved network traffic data, and sends them to director function **102**, as earlier described, blocks **504-506**. Upon transmission, report function **304** returns to block **502**.

For command application function **306**, as illustrated in **fig. 6**, upon start up, it awaits for regulation/de-regulation instructions from director **102**, block **602**. Upon receipt of regulation/de-regulation instructions, command application function **306**

generates the appropriate commands for the particular router/routers the sensor function is responsible, and queues the commands for transmission to the router/routers, as alluded to earlier. Upon generating and queuing the appropriate commands, generation function **306** returns to block **602** to await additional regulation/de-regulation instructions from director function **102**.

**Figure 7** illustrates an architectural view of a standalone sensor, implementing the earlier described sensor function **104**, in accordance with a hardware/firmware implementation. As illustrated, sensor **700** includes processor **702**, non-volatile memory **704**, LAN and WAN interfaces **706** and **708**. Processor **702** and non-volatile memory **704** are intended to represent a broad range of these elements known in the art. In the case of processor **702**, it may be any 8-bit/16-bit micro-controllers, or 16-bit/32-bit digital signal processors, or even more powerful general purpose microprocessors known in the art. Non-volatile memory **704** may be EEPROM, Flash memory or other memory of the like. Non-volatile memory **704** is employed to store the firmware implementing the earlier described request, report and command generation functions of sensor **700**, and for the embodiment, facilitates these functions execution in place. LAN interface **706** may be an Ethernet, Token Ring or other LAN interfaces of like kind. WAN interface **708** may be a modem, or an ISDN or DS3 adapter as well as other higher speed interfaces.

In an alternate embodiment, request, report and command application functions **302-306** of **Fig. 3**, may be implemented in software via high level languages such as C, and the software implementation may be hosted by a computing device near its responsible router/routers, provided the hosting computing device is properly equipped with the appropriate communication interfaces to communicate with its responsible router/routers, and director function **102**.

In yet other embodiments, as alluded to earlier, request, report and command application functions **302-306** of **Fig. 3**, may be incorporated as an integral part of its responsible router. In these embodiments, instead of gathering the network traffic data via request/reply transaction conducted over a communication protocol, request function **302** may gather the network traffic data through bus transactions, such as direct memory access (DMA) operations accessing the appropriate internal storage units of the router for the collected data. Similarly, in lieu of applying commands designed for a command interface, command application functions may directly invoke the applicable router routines to cause the routing operation alteration to be effectuated instead.

<u>Director</u>

Referring now to **fig. 8**, wherein a component view of director function **102**, in accordance with one embodiment is shown. As illustrated, director function **102** is also implemented on a standalone device outside of the monitored/regulated routers **106a-106b**. Director function **102** includes send/receive function **802**, analyzer **804**, and regulator **806**, operatively coupled to each other as shown. Send/receive function **802** is employed to receive network traffic data reported by sensor functions **104**, and to send regulation/de-regulation instructions to the applicable sensor functions or the routers directly. Analyzer **804** analyzes the network traffic data reported to determine if the networking device of interest is meeting its service level goals/commitments, whether regulation/de-regulation actions need to be taken to regulate selected network traffics to enhance the likelihood of the networking device of interest being able to meet their service level goals/commitments, and alerts regulator **806** accordingly. In one embodiment, analyzer **804** determines whether the networking device of interest are meeting its service level goals/commitments,

and whether a group of other network traffics are to be regulated/deregulated, based on the reported data, as described earlier. Regulator **806** is used to determine the location or locations of regulation/de-regulation (i.e. the routers), and what the regulation/de-regulation actions should be.

**Figures 9-10** illustrate the operational flow of the relevant aspects of the send/receive, analyzer and regulation functions **802-806**, in accordance with one embodiment each. As illustrated in **Fig. 9**, for the send/receive function, upon start up, it determines if there are network traffic data to be received from the sensors, block **902**. If there are, send/receive function **802** receives the network traffic data being reported accordingly. If there are not, send/receive function **802** determines if there are regulation/de-regulation instructions to be sent to the sensors. If there are, send/receive function **802** sends the regulation/regulation instructions accordingly. If there are not, send/receive function **802** returns to block **902** to determine if there are data to be received again.

As illustrated in **fig. 10**, upon start up, analyzer **804** determines if there are networking devices to be analyzed, block **1002**. If there are not, it awaits for the "enrollment" of a networking device of interest. If there are, analyzer **804** selects a networking device to be analyzed, block **1004**. Analyzer **804** first determines if the networking device is meeting its service level goals/commitments, block **1006**. If the networking device is meeting its service level goals/commitments, analyzer **804** further determines if regulation of a group of other network traffics are currently being administered on behalf of the networking device to enhance its ability to meet the service level goals/commitments, block **1008**. If either the networking device is not meeting its service level goals/commitments, and at least one other group of network traffic is contributing to the non-meeting of the service level goals/commitments, or the networking device is consistently meeting its service level

goals/commitments, and regulation is being administered on its behalf, analyzer **804** notifies regulator **806** accordingly.

As illustrated in **Fig. 11**, upon receipt of an alert, regulator **806** determines if the alert is for regulation or de-regulation, block **1102**. If the alert is for regulation, regulator **806** selects the locations to be regulated, block **1106**. Further, regulator **806** also determines the level of regulation, e.g. how much bandwidth to reduce, or how many priority levels to drop, with respect to the target network traffic, block **1108**. In one embodiment, the moderations are made in pre-determined small quantities and iteratively increased. Upon making these determinations, regulator **806** provides the appropriate sensor functions (or the routers directly) with the regulation/de-regulation instructions accordingly, block **1114**. In alternate embodiments, the amount of moderations may be determined through the employment of predictive models. On the other hand, if the alert is for de-regulation, regulator **806** selects the "outermost" regulated routers for de-regulation, block **1110**. Further, regulator **806** determines the level of de-regulation, e.g. how much bandwidth to increase, or how many priority levels to bump up, block **1112**. Similarly, the relaxations are made in pre-determined small quantities and iteratively increased, or in alternate embodiments, in accordance with selected predictive models. Upon making these determinations, regulator **806** provides the appropriate sensor functions (or the routers directly) with the regulation/de-regulation instructions accordingly, block **1114**.

## Example Host Computer System

**Figure 12** illustrates an example computer system suitable for use as either a host to a software implementation of a sensor, or the director in accordance with one embodiment. As shown, computer system **1200** includes one or more

processors **1202** (typically depending on whether it is used as host to sensor or the director), and system memory **1204**. Additionally, computer system **1200** includes mass storage devices **1206** (such as diskette, hard drive, CDROM and so forth), input/output devices **1208** (such as keyboard, cursor control and so forth) and communication interfaces **1210** (such as network interface cards, modems and so forth). The elements are coupled to each other via system bus **1212**, which represents one or more buses. In the case of multiple buses, they are bridged by one or more bus bridges (not shown). Each of these elements perform its conventional functions known in the art. In particular, system memory **1504** and mass storage **1506** are employed to store a working copy and a permanent copy of the programming instructions implementing the teachings of the present invention. The permanent copy of the programming instructions may be loaded into mass storage **1206** in the factory, or in the field, as described earlier, through a distribution medium (not shown) or through communication interface **1210** (from a distribution server (not shown). The constitution of these elements **1202-1212** are known, and accordingly will not be further described.

<u>Conclusion and Epilogue</u>

Thus, it can be seen from the above descriptions, a novel method and apparatus for distributively managing service level commitments has been described. The novel scheme enables the quality of service provided by a networking device to be ensured, including nullification of denial of service attacks, without imposing the burden of management on the networking device itself.

While the present invention has been described in terms of the above illustrated embodiments, those skilled in the art will recognize that the invention is not limited to the embodiments described. The present invention can be practiced with

modification and alteration within the spirit and scope of the appended claims. For examples, as alluded to earlier, the present invention may be practiced with more or less sensors, more directors, and so forth. Further, regulations may be applied or relaxed in response to the assumption of additional or removal of service level goals/commitments by the networking device of interest. Alternatively, as opposed to causing regulations to be automatically applied or relaxed, at least some of the regulation/de-regulation may be suggested to a networking administrator instead.

Thus, the description is thus to be regarded as illustrative instead of restrictive on the present invention.